AP Biology

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Contents

0.1 Elements

- **Elements**: are substances that cannot be broken down into simpler substances by chemical means.
- Oxygen (O), carbon (C), hydrogen (H), and nitrogen (N).
- These four elements are used to build biological molecules, such as carbohydrates, proteins, lipids, and nucleic acids. They are also used to form storage compounds and cells in all organisms.
- Some elements are known as **trace elements** because they are required by an organism only in very small quantities. They include iron (Fe), iodine (I), and copper (Cu).
- Other elements are present but in smaller quantities.

0.2 Subatomic Particles

- **Atoms** are the unit of life and are the building blocks of the physical world.
  - Protons are positively charged (+) particles
  - Neutrons are uncharged particles.
  - Electrons are negatively charged (–) particles
- Some atoms have the same number of protons but differ in the number of neutrons in the nucleus. These are called isotopes.

0.3 Compounds

- Consists of two or more elements
- The atoms of a compound are held together by chemical bonds, which may be ionic bonds, covalent bonds, or hydrogen bonds.
- An **ionic bond** is formed between two atoms when one or more electrons are transferred from one atom to the other.
- The charged forms of the atoms are called ions.
- A **covalent bond** is formed when electrons are shared between atoms. If the electrons are shared equally between the atoms, the bond is called non-polar covalent. If the electrons are shared unequally, the bond is called polar covalent.

0.4 Water: The Versatile Molecule

- Hydrogen bonds are **weak chemical bonds that form when a hydrogen atom that is covalently bonded to one**
- The hydrogen bonds that hold water molecules together contribute to a number of special properties, including cohesion, adhesion, surface tension, high heat capacity, and expansion on freezing.
- Water molecules have a strong tendency to stick together. This exhibits **cohesive forces.**
- Water molecules also like to stick to other substances—This makes them **adhesive**
- These two forces taken together—cohesion and adhesion—account for the ability of water to rise up the roots, trunks, and branches of trees. This is **capillary action.**
- The cohesion of water molecules contributes to another property of water known as surface tension. The surface of the water has tension to it. The water molecules are stuck together, and light things like leaves and water striders can sit atop the surface without sinking.

0.5 Acids and bases

- Reactions are also influenced by whether the solution in which they occur is **acidic, basic, or neutral.**
- A solution is acidic if it contains a lot of hydrogen ions (H+). If you dissolve an acid in water, it will release a lot of hydrogen ions.
- Bases do not release hydrogen ions when added to water. They release a lot of hydroxide ions (OH–).
- The acidity or alkalinity of a solution can be measured using a pH scale. The pH scale is numbered from 1 to 14. The midpoint, 7, is considered neutral pH.
- The concentration of hydrogen ions in a solution will indicate whether it is acidic, basic, or neutral.
  - pH = –log [H+]
- The pH scale is logarithmic and represents a tenfold change in hydrogen ion concentration.

0.6 Organic molecules

- Molecules with carbon are organic molecules and molecules that do not contain carbon atoms are called inorganic compounds.
- Carbon is important for life because it is a **versatile atom, meaning that it has the ability to bind not only with other carbons but also with a number of other elements including nitrogen, oxygen, and hydrogen**
- Polymers are chains of building blocks in **macromolecules**
- Monomers are the individual building blocks of a polymer
- Polymers are formed through dehydration synthesis (or condensation) reactions. A water molecule is lost in the reaction, and a larger compound is formed.
- Hydrolysis is when polymers can also be broken down into monomers.
- The water breaks the bond between the two monomers.
- Four classes of organic compounds central to life on Earth:
  1. carbohydrates
  2. proteins
  3. lipids
  4. nucleic acids

0.6.1 Carbohydrates

- Carbohydrates are organic compounds that contain carbon, hydrogen, and oxygen. They are in a ratio of approximately **1:2:1**
- Most carbohydrates are categorised as either monosaccharides, disaccharides, or polysaccharides. The term saccharides means "sugar." The prefixes refer to the number of sugars in the molecule.

0.6.2 Monosaccharides:

- It is an **energy source** for cells.
- The two most common sugars are glucose and fructose. Their chemical formula is C6H12O6
- Glucose is an important part of the food we eat, and it is the product made by plants during photosynthesis.
- Glucose and fructose can be depicted as either "straight" or "rings." They have OHs and Hs attached to them.

0.6.3 Disaccharides

- When two monosaccharides are joined, the bond is called a **glycosidic linkage,** and the resulting sugar is called a disaccharide. The disaccharide formed from two glucose molecules is maltose.
- To break up the disaccharide and form two monosaccharides - Just add water.

0.6.4 Polysaccharides

- Polysaccharides are made up of many repeated units of monosaccharides.
- They can consist of branched or unbranched chains of monosaccharides. Need to know for the test : starch, cellulose, and glycogen.
- Glycogen and starch are sugar storage molecules. Glycogen stores sugar in animals and starch stores sugar in plants.
- Cellulose, on the other hand, is made up of -glucose and is a major part of the cell walls in plants. Its function is to lend **structural support.**
- Chitin, a polymer of -glucose molecules, serves as a structural molecule in the walls of fungus and in the exoskeletons of arthropods.

0.6.5 Proteins

- Proteins are important for structure, function, and regulation of your tissues and organs.
- Amino acids are building blocks of proteins. They contain carbon, hydrogen, oxygen, and nitrogen atoms. There are 20 different amino acids.
- Proteins have four important parts around a central carbon:
  - An amino group (–NH2), a carboxyl group (–COOH), a hydrogen, and an R-group.
- Amino acids differ only in the R-group, which is also called the side chain.
- When it comes to spotting an amino acid, look for the amino group (NH2), then look for the carboxyl molecule (COOH).
- Side chain polarity affects whether an amino acid is more hydrophobic or more hydrophilic.
- The AP Exam divides them into 3 broad categories: hydrophobic (non-polar and uncharged), hydrophilic (polar and uncharged), and ionic (polar and charged).
- Of the common amino acids:
  - Two (glutamic acid and aspartic acid) donate a proton, making them negatively charged.
  - Two (lysine and arginine) accept a proton at physiological pH, which makes them positively charged.
- Two contain the atom sulphur: methionine and cysteine.

0.6.6 Polypeptides

- When two amino acids join, they form a **dipeptide**. The carboxyl group of one amino acid combines with the amino group of another amino acid.
- The bond between two amino acids is **peptide bond.**
- If a group of amino acids is joined together in a "string," the resulting organic compound is called a polypeptide. Once a polypeptide chain twists and folds on itself, it forms a 3D structure called a protein.

- The linear sequence of the amino acids is the primary structure of a protein.
- When the polypeptide begins to twist it begins forming either a coil **(known as an alpha helix) or zigzagging pattern (known as beta-pleated sheets).** These are secondary structures.
- When the secondary structure reshapes the polypeptide, amino acids that were far away in the primary structure arrangement can now also interact with each other. This is called the tertiary structure.
- When different polypeptide chains sometimes interact with each other, they form a quaternary structure. Haemoglobin is a molecule in the blood that helps distribute oxygen to the tissues in the body. It is formed when four separate polypeptide chains interact with each other and is a quaternary structure.

0.6.7 Liplids

- This consists of carbon, hydrogen, and oxygen atoms.
- The most common examples of lipids are triglycerides, phospholipids, and steroids.
- Lipids are important due to their non-polar structures, they function as structural components of cell membranes, sources of insulation, signalling molecules, and a means of energy storage.
- Our bodies store fat in tissue called, adipose, which is made of cells called adipocytes; these cells are filled with lipids called **triglycerides**.
- Each triglyceride is made of a glycerol molecule (also called the glycerol backbone) with three fatty acid chains attached to it. A fatty acid chain is covered in hydrogen. One end of the chain has a carboxyl group.
- A fatty acid can be saturated with hydrogens along its long carbon chain or it can't be unsaturated. If there is a double bond in the chain it is an unsaturated fatty acid.
- **Lipid Saturation**Unknown Node :: textDirective extent of saturation in a lipid can affect its structure and function. The more double bonds that exist within a lipid, the more unsaturated it is.

0.6.8 Phospholipids

- Phospholipids contain two fatty acid "**tails**" and one negatively charged phosphate "**head**".
- Phospholipids are important because of some unique properties they possess, regards to water.
- The two fatty acid tails are hydrophobic. The reason for this is that fatty acid tails are non-polar, and non-polar substances don't mix well with polar ones, such as water.
- The phosphate "head" of the lipid is hydrophilic, meaning that it does mix well with water since it carries a negative charge, and this charge draws it to the positively charged end of a water molecule.
- A phospholipid has both a hydrophilic region and a hydrophobic region which makes it is an amphipathic molecule.

0.6.9 Cholesterol

- Cholesterol is a **four-ringed** molecule that is found in membranes.
- It generally increases membrane fluidity, except at very high temperatures. Cholesterol is also important for making certain types of hormones and for making vitamin D.

0.6.10 Nucleic Acids

- They contain carbon, hydrogen, oxygen, and nitrogen and phosphorus. Nucleic acids are molecules that are made up of simple units called nucleotides.
- DNA contains the hereditary "**blueprints**" of all life. RNA is essential for protein synthesis

0.7 Living things

- **Cell** is life's basic unit of structure and function
- As cells increase in volume, the surface area-to-volume ratio decreases, and the exchange of materials becomes less efficient. The surface area and volumes of cells can be calculated using typical geometry formulas.
- The **surface area-to-volume ratio** concept can also be applied to organisms. As organisms increase in size, their ratio will decrease and this can affect properties of the organism, such as heat-exchange with their surroundings. Small organisms lose heat at much higher rates than larger organisms as a result of their efficient exchange of heat.

0.8 Types of cells and organelles

- **Light microscopes** are used to study stained or living cells. They can magnify the size of an organism up to 1,000 times.
- **Electron microscopes** are used to study detailed structures of a cell that cannot be easily seen or observed by light microscopy.
- There are two distinct types of cells: prokaryotic cells and eukaryotic cells.

0.8.1 Prokaryotic cell

- It is a lot **smaller** than a eukaryotic cell and simpler. Bacteria and archaea are examples of prokaryotes.
- The inside of the cell is filled with a substance called cytoplasm.
- The genetic material in a prokaryote is one continuous, circular DNA molecule that is found free in the cell in the nucleoid.
- Most prokaryotes have a cell wall composed of peptidoglycans that surrounds a lipid layer called the plasma membrane.
- Prokaryotes also have small ribosomes.
- Some bacteria may also have one or more flagella, which are used for motility and they might have a thick capsule outside their cell wall for extra protection.
- Prokaryotes do not have any membrane-bound organelles. Their only membrane is the plasma membrane

0.8.2 Eukaryotic cell

- Eukaryotic cells are more complex. Fungi, protists, plants, and animals are examples of **eukaryotes**.
- Eukaryotic cells have many smaller structures called **organelles**. Some of these organelles are the same structures seen in prokaryotic cells, but many are uniquely eukaryotic.

0.8.3 Plasma Membrane

- It is the outer envelope of the cell, made up of mostly **phospholipids and proteins.**
- The plasma membrane is important because it regulates the movement of substances into and out of the cell. The membrane is **semipermeable**.
- Many proteins are associated with the cell membrane. Some of these proteins are loosely associated with the lipid bilayer (**peripheral proteins)**. They are located on the inner or outer surface of the membrane.
- Others are firmly bound to the plasma membrane (integral proteins). These proteins are **amphipathic**.

- Some integral proteins extend all the way through the membrane (transmembrane proteins).
- This arrangement of phospholipids and proteins is known as the **fluid- mosaic model.**
- Adhesion proteins form junctions between adjacent cells.
- **Receptor proteins** such as hormones, serve as docking sites for arrivals at the cell.
- Transport proteins form pumps that use ATP to actively transport solutes across the membrane.
- Channel proteins form **channels that selectively allow the passage of certain ions or molecules.**
- Cell surface markers such as **glycoproteins**, and some **lipids**, such as glycolipids, are exposed on the extracellular surface and play a role in cell recognition and adhesion. .
- **Carbohydrate** side chains are found only on the outer surface of the plasma membrane

0.8.4 The Nucleus

- The nucleus is usually the **largest organelle in the cell.** The nucleus not only directs what goes on in the cell, but is also responsible for the cell's ability to reproduce. It's the home of the **hereditary information**—DNA—which is organized into large structures called **chromosomes**. The most visible structure within the nucleus is the nucleolus, which is where rRNA is made and ribosomes are assembled.

0.8.5 Ribosomes

- The ribosomes are **sites of protein synthesis**. Their job is to manufacture all the proteins required by the cell or secreted by the cell. Ribosomes are round structures composed of two subunits, the large subunit and the small subunit. The structure is composed of ribosomal RNA (rRNA) and proteins. Ribosomes can be either free floating in the cell or attached to another structure called the endoplasmic reticulum (ER)

0.8.6 Endoplasmic Reticulum (ER)

- The ER is a **continuous channel that extends into many regions of the cytoplasm and provides mechanical support and transportation.** The rough ER compartmentalises the cell.
- The region of the ER that lacks ribosomes is called the smooth ER. The smooth ER makes lipids, hormones, and steroids and breaks down toxic chemicals.

0.8.7 Golgi Complex

- After the ribosomes on the rough ER have completed synthesizing proteins, the Golgi complex modify, process, and sort the products.
- They're the **packaging and distribution centers** for materials destined to be sent out of the cell. They package the final products in little sacs called vesicles, which carry products to the plasma membrane.

0.8.8 Mitochondria

- They're power stations responsible for converting energy from organic molecules into useful energy for the cell. The most common energy molecule in the cell is adenosine triphosphate (ATP).
- It consists of an **inner portion and an outer portion**. The inner mitochondrial membrane forms folds known as **cristae** and separates the innermost area (the matrix) from the inter-membrane space. The outer membrane separates the inter-membrane space from the cytoplasm.

0.8.9 Lysosomes

- They have sacs that carry **digestive enzymes**, which they use to break down old, worn-out organelles, debris, or large ingested particles.
- Lysosomes are made when vesicles containing specific enzymes from the trans Golgi **fuse with vesicles** made during endocytosis. Lysosomes are also essential during programmed cell death called apoptosis.

0.8.10 Vacuoles

- They are fluid-filled sacs that **store water, food, wastes, salts, or pigments.** Vacuoles serve multiple functions in plant cells.

0.8.11 Peroxisomes

- **Peroxisomes** are organelles that detoxify various substances, producing hydrogen peroxide (H2O2) as a byproduct. They have enzymes that break down hydrogen peroxide into oxygen and water.

0.8.12 Cytoskeleton

- The shape of a cell is determined by a network of protein fibers called the **cytoskeleton**. The most important fibers are microtubules and **microfilaments**.
- **Microtubules** are made up of the protein tubulin, participate in cellular division and movement.
- **Microfilaments** are important for movement. These thin, rodlike structures are composed of the protein actin. Actin monomers are joined together and broken apart as needed to allow microfilaments to grow and shrink.

0.8.13 Cilia and Flagella

- Cilia and flagella have **locomotive properties** in single-celled organisms. The **beating motion** of cilia and flagella structure allows it to move.

0.8.14 Plant Cells Versus Animal Cells

- Plant cells, unlike animal cells, have a cell wall (made of cellulose). A cell wall is a rigid layer just outside the plasma membrane that provides support for the cell.
- Plant cells possess chloroplasts, which have a double outer membrane. Chloroplasts contain **chlorophyll**, which gives plants their characteristic green color.
- Cytoplasm within a plant cell is usually taken up by a large vacuole which is the central vacuole.
- Plant cells also differ from animal cells in that plant cells do not contain **centrioles**.

0.9 Transport: traffic across membranes

- The ability of molecules to move across the cell membrane depends on:
    1. the semipermeability of the plasma membrane
    2. the size and charge of particles that want to get through
- Small substances cross the membrane without any resistances since "like dissolves like." The lipid bilayer has **hydrophilic** outside and **hydrophobic** on the inside so only hydrophobic things can pass that central zone. If a substance is hydrophilic, the bilayer won't let it pass without assistance, called facilitated transport
- **Aquaporins** are water-specific channels. Glucose and ions such as Na+ and K+ are also transported across the plasma membrane via membrane proteins. Membranes may become polarised as these ions move across them.

0.9.1 Passive Transport: Simple and Facilitated Diffusion

- If there is a high concentration of something in one area, it will move to spread out and diffuse into an area with a lower concentration. The substance moves down a concentration gradient. This is called **diffusion**.
- When the molecule that is diffusing is **hydrophobic**, the diffusion is called simple diffusion because the small non-polar molecule can just drift right through the membrane without trouble.
- When the diffusion requires the help of a channel-type protein, it is called **facilitated diffusion.**
- Anytime that a substance is moving by diffusion, it is called passive transport because there is no outside energy required to power the movement.

0.9.2 Osmosis

- The only difference is that in diffusion the membrane is usually permeable to solute, and in osmosis it is not.
- In plants, the cell wall is important to protect it against osmotic changes, while the cell membrane can shrink away from the wall (a process called plasmolysis) if it loses water and can expand and squeeze tightly against the cell wall if it takes in water.
- **Tonicity** is used to describe osmotic gradients.
- If an environment is isotonic to the cell, the solute concentration is the same inside and outside.
- A hypertonic solution has more total dissolved solutes than the cell, while a hypotonic solution has less.
- **Water potential ()** is the measure of potential energy in water and describes the eagerness of water to flow from an area of high water potential to an area of low water potential.
- It is affected by: pressure potential (p) and solute potential (s)

Solute Potential of a Solution s = iCRT where: i = ionization constant C = molar concentration R = pressure constant T = temperature in Kelvin (°C + 273)

Adding a solute lowers the water potential of a solution, causing water to be less likely to leave this solution and more likely to flow into it. The more solute molecules present, the more negative the solute potential is.

0.9.3 Active Transport

- Movement against the natural flow is called **active transport.**
- Some proteins in the plasma membrane are powered by ATP.
- An example of active transport is a special protein called the sodium-potassium pump. It ushers out three sodium ions (Na+) and brings in two potassium ions (K+) across the cell membrane. This pump depends on ATP to get ions across that would otherwise remain in regions of higher concentration.
- **Primary active transport** occurs when ATP is directly utilised to transport something.
- **Secondary active transport** occurs when something is actively transported using the energy captured from the movement of another substance flowing down its concentration gradient.

0.9.4 Endocytosis

- When the particles that want to enter a cell are just too large, the cell uses a portion of the cell membrane to engulf the substance. The cell membrane forms a pocket, pinches in, and eventually forms either a vacuole or a vesicle. This process is called endocytosis.
- Three types of endocytosis : pinocytosis, phagocytosis, and receptor- mediated endocytosis.

- **Pinocytosis**: the cell ingests liquids.
- **Phagocytosis**: the cell takes in solids.
- **Receptor-mediated endocytosis:** involves cell surface receptors that work in tandem with endocytic pits that are lined with a protein called clathrin. When a particle, or ligand, binds to one of these receptors, the ligand is brought into the cell by the invagination, or "folding in" of the cell membrane. A vesicle then forms around the incoming ligand and carries it into the cell's interior.

0.9.5 Bulk Flow

- **Bulk flow** is the one-way movement of fluids brought about by pressure.
- Example: movement of blood through a blood vessel and the movement of fluids in xylem and phloem of plants are examples of bulk flow.

0.9.6 Dialysis

- Dialysis is the **diffusion** of solutes across a selectively permeable membrane.
- **Kidney dialysis** is a specialized process by which the blood is filtered by using machines and concentration gradients.

0.9.7 Exocytosis

- In exocytosis, a cell **ejects waste products or specific secretion** products, such as hormones, by the fusion of a vesicle with the plasma membrane, which then expels the contents into the extracellular space. Exocytosis is basically reverse endocytosis.

0.10 Bioenergetics

The study of how cells accomplish this is called **bioenergetics**.

0.10.1 Thermodynamics

Energy cannot be created or destroyed, it can be only be transferred.

- **First Law of Thermodynamics**: Cells cannot take energy out of thin air. It must harvest it from somewhere.
- **Second Law of Thermodynamics: It states that energy transfer leads to less organization. That means the universe tends toward disorder (entropy). In order to power cellular processes, energy input must exceed energy loss to maintain order. Cellular processes that release energy can be coupled with cellular processes that require an input of energy.**

0.10.2 Types of Reactions

- **Exergonic** reactions are those in which the products have less energy than the reactants.
- The course of a reaction can be represented by an energy diagram. You'll notice that **energy is represented along the y-axis.**
- Reactions that require an input of energy are called endergonic reactions. You'll notice that the products have more energy than the reactants.

0.11 Enzymes

- A **catalyst** is something that speeds something up.
- Enzymes are **biological catalysts** that speed up reactions which is by lowering the activation energy and helping the transition state to form.
- Enzymes do NOT change the energy of the starting point or the ending point of the reaction. They only lower the activation energy.

0.11.1 Enzyme Specificity

- Each enzyme catalyzes only one kind of reaction. This is known as **enzyme specificity**.
- Enzymes are usually named after the molecules they target. In enzymatic reactions, the targeted molecules are known as **substrates**.

0.11.2 Enzyme-Substrate Complex

- During a reaction, the enzyme's job is to bring the transition state about by helping the substrate(s) get into position. It accomplishes this through a special region on the enzyme known as an **active site.**
- The enzyme temporarily binds one or more of the substrates to its active site and forms an **enzyme-substrate complex.**
- Enzymes **Do**: increase the rate of a reaction by lowering the reaction's activation energy form temporary enzyme-substrate complexes remain unaffected by the reaction
- Enzymes **Don't**: change the reaction make reactions occur that would otherwise not occur at all

0.11.3 Induced-fit

- Enzymes and substrates don't fit together quite so seamlessly. Enzymes have to change its shape slightly to accommodate the shape of the substrates. This is called **induced-fit.**
- Because the fit between the enzyme and the substrate must be perfect, enzymes operate only under a strict set of biological conditions.

0.11.4 Enzymes Don't Always Work Alone

- Enzymes sometimes need a little help in catalysing a reaction. Those factors are known as **cofactors**. Cofactors can be either organic molecules called coenzymes or inorganic molecules or ions.
- Inorganic cofactors are usually metal ions (Fe2+, Mg2+).
- Vitamins are examples of organic coenzymes

0.11.5 Factors Affecting Reaction Rates

- Enzymatic reactions can be influenced by a number of factors, such as temperature and pH. The concentrations of enzyme and substrate will also determine the speed of the reaction.

0.11.6 Temperature

- The rate of a reaction increases with increasing temperature.
- An increase in the temperature of a reaction increases the frequency of collisions among the molecules. But too much heat can damage an enzyme and becomes **denatured**.
- Enzyme denaturation is reversible if the original optimal environmental conditions of the enzyme are restored.

0.11.7 pH

- Enzymes also function best at a particular pH.
- At an incorrect pH, the hydrogen bonds can be **disrupted** and the structure of the enzyme can be altered

0.11.8 Relative Concentration of Substrates and Products

- The relative concentration of substrates and products can also affect the **rate** of an enzyme-catalysed reaction.
- An increase in substrate concentration will initially speed up the reaction. However, once all of the enzyme in solution is bound by substrate, the reaction can no longer speed up.
- This concentration of substrate where all of the enzyme in a reaction is bound by substrate is called the **saturation point.** Additional substrate past this point will no longer increase the speed of the reaction.

0.11.9 Enzyme Regulation

- A cell can control enzymatic activity by regulating the conditions that influence the shape of the enzyme.
- Enzymes can be turned on or off by things that bind to them. Sometimes these things can bind at the active site, and sometimes they bind at other sites, called **allosteric sites.**
- If the substance has a shape that fits the active site of an enzyme it can compete with the substrate and block the substrate from getting into the active site. This is called competitive inhibition. You can always identify a competitive inhibitor based on what happens when you flood the system with lots of substrate.
- If the inhibitor binds to an allosteric site, it is an allosteric inhibitor and it is noncompetitive inhibition. A noncompetitive inhibitor generally distorts the enzyme shape so that it cannot function. The substrate can still bind at the active site, but the enzyme will not be able to catalyze the reaction.

0.12 Reaction Coupling and ATP

- The cell gets its energy through adenosine triphosphate (**ATP**).
- ATP consists of a molecule of adenosine bonded to three phosphates. Enormous amount of energy is packed into those phosphate bonds.
- When a cell needs energy, it takes one of these potential-packed molecules of ATP and splits off the third phosphate, forming adenosine diphosphate (ADP) and one loose phosphate (Pi), while releasing energy in the process. ATP $\rightarrow$ ADP + Pi + energy
- Organisms can use exergonic processes that increase energy, like breaking down ATP, to power **endergonic reactions,** like building organic macromolecules.

0.12.1 Sources of ATP

- ATP comes from a process called **cellular respiration.**
- Cellular respiration is a process of breaking down sugar and making ATP.
- In **autotrophs**, the sugar is made during photosynthesis.
- In **heterotrophs**, glucose comes from the food we eat.

0.13 Photosynthesis

- **Photosynthesis** is the process by which light energy is converted to chemical energy.
- 6CO2 + 6H2O C6H12O6 + 6O2
- You'll notice from this equation that carbon dioxide and water are the raw materials used to manufacture simple sugars. Oxygen is one of the products of photosynthesis.
- There is strong evidence that prokaryotic photosynthesis contributed to the production of oxygen in the atmosphere. Furthermore, prokaryotic photosynthesis pathways laid the evolutionary foundation for eukaryotic photosynthesis to develop.
- There are two stages in photosynthesis: the light reactions (also called the light-dependent reactions) and the dark reactions (also called the light- independent reactions).
  - The whole process begins when photons (energy units) of sunlight strike a leaf, activating chlorophyll and exciting electrons.
  - The activated chlorophyll molecule then passes these excited electrons down to a series of electron carriers, ultimately producing ATP and NADPH.
  - Both of these products, along with carbon dioxide, are then used in the dark reactions (light-independent) to make carbohydrates.
  - Along the way, water is also split and oxygen gets released.

0.13.1 Chloroplast Structure

- The leaves of plants contain lots of chloroplasts, which are the **primary sites of photosynthesis.**
- If you split the membranes of a chloroplast, you'll find a fluid-filled region called the stroma. Inside the stroma are structures that look like stacks of coins. These structures are the grana.
- The many disk-like structures that make up grana are called thylakoids. They contain chlorophyll, a light-absorbing pigment that drives photosynthesis, as well as enzymes involved in the process.
- The very inside of a thylakoid is called the thylakoid lumen.
- Many light-absorbing pigments participate in photosynthesis. Some of the more important ones are chlorophyll a, chlorophyll b, and carotenoids. These pigments are clustered in the thylakoid membrane into units called antenna complexes.
- All of the pigments within a unit are able to "gather" light, but they're not able to "excite" electrons. The other pigments, called antenna pigments, "gather" light and "bounce" energy to the reaction center.
- There are two types of reaction centers:
  - photosystem I (PS I) and photosystem II (PS II). T
- The principal difference between the two is that each reaction center has a **specific type of chlorophyll—chlorophyll a—that absorbs a particular wavelength of light.**
- Autotrophs are using light and ADP and phosphates (that's phosphorylation) to produce ATP. An absorption spectrum shows how well a certain pigment absorbs electromagnetic radiation. Light absorbed is plotted as a function of radiation wavelength. This spectrum is the opposite of an emission spectrum, which gives information on which wavelengths are emitted by a pigment.
- **Carotenoids** absorb light on the blue-green end of the spectrum, but not on the other end. This is why plants rich in carotenoids are yellow, orange, or red.

0.14 The Light Reactions

- When a leaf captures sunlight, the energy is sent to **P680, the reaction center for photosystem II.**
- The activated electrons are trapped by P680 and passed to a molecule called the primary acceptor, and then they are passed down to carriers in the electron transport chain.
- To replenish the electrons in the thylakoid, water is split into oxygen, hydrogen ions, and electrons. That process is called photolysis.
- The electrons from photolysis replace the missing electrons in photosystem II. As the energized electrons from photosystem II travel down the electron transport chain, they pump hydrogen ions into the thylakoid lumen. A proton gradient is established. As the hydrogen ions move back into the stroma through ATP synthase, ATP is produced.
- After the electrons leave photosystem II, they go to photosystem I. The electrons are passed through a second electron transport chain until they reach the final electron acceptor NADP+ to make NADPH. Photosystem I and photosystem II were numbered in order of their discovery, not the order they are used in photosynthesis.

0.14.1 The Light-Independent Reactions

- The dark reactions use the products of the light reactions—ATP and NADPH—to **make sugar**.
- We now have energy to make glucose, Their carbon source is CO2. Carbon fixation means is that CO2 from the air is converted into carbohydrates.
- This step occurs in the stroma of the leaf. The dark reactions are also called the **Calvin-Benson Cycle**

Plants that live in hot climates have evolved two different ways around this:

- CAM plants deal with this problem by temporally separating carbon fixation and the Calvin cycle.
- They open their stomata at night and incorporate CO2 into organic acids.
- During the day, they close their stomata and release CO2 from the organic acids while the light reactions run.
- In contrast, C4 plants have slightly different leaf anatomy that allows them to perform CO2 fixation in a different part of the leaf from the rest of the Calvin cycle. This prevents photorespiration.
- C4 plants produce a four- carbon molecule as the first product of carbon fixation and perform cyclic electron flow in the light reactions.

0.15 Cellular Respiration

- $C6H12O6 + 6O2 \rightarrow 6CO2 + 6H2O + ATP$
- You can break cellular respiration down into two different approaches:
- aerobic respiration and anaerobic respiration.
- If ATP is made in the presence of oxygen, we call it aerobic respiration. If oxygen
- If it isn't present, we call it anaerobic respiration.

0.15.1 Introduction to Aerobic Respiration

Aerobic respiration consists of four stages containing a series of coupled reactions that establish an electrochemical gradient across membranes:

1. glycolysis
2. formation of acetyl-CoA
3. the Krebs (citric acid) cycle
4. oxidative phosphorylation (the electron transport chain + chemiosmosis)

0.15.2 Stage 1: Glycolysis

- The first stage begins with glycolysis, the splitting of glucose
  - Glucose is a six-carbon molecule that is broken into two three- carbon molecules called pyruvic acid.
  - This breakdown of glucose also results in the net production of two molecules of ATP and two molecules of NADH.
  - Glucose + 2 ATP + 2NAD+ $\rightarrow$ 2 Pyruvic acid + 4 ATP + 2NADH
  - Glycolysis also creates two NADH, which result from the transfer of electrons to the carrier NAD+, which then becomes NADH.
  - NAD+ and NADH are constantly being turned into each other as electrons are being carried and then unloaded.

There are four important tidbits to remember regarding glycolysis:

- occurs in the cytoplasm
- net of 2 ATPs produced
- 2 pyruvic acids formed
- 2 NADH produced

0.15.3 Stage 2: Formation of Acetyl-CoA

- Pyruvic acid is **transported to the mitochondrion.**
- Each pyruvic acid (a three-carbon molecule) is converted to acetyl-coenzyme
- A (a two-carbon molecule, usually just called acetyl-CoA) and CO2 is released.
- 2 Pyruvic acid + 2 Coenzyme A + 2NAD+ $\rightarrow$ 2 Acetyl-CoA + 2CO2 + 2NADH
- From two 3- carbon molecules to now two 2-carbon molecules.
- The extra carbons leave the cell in the form of CO2. Once again, two molecules of NADH are also produced for each glucose you started with.
- This process of turning pyruvic acid into acetyl-CoA is catalyzed by an enzyme complex called the pyruvate dehydrogenase complex (PDC).

0.15.4 Stage 3: The Krebs Cycle

- Also known as the **citric acid cycle.**
  - The Krebs cycle begins with each molecule of acetyl-CoA produced from the second stage of aerobic respiration combining with oxaloacetate, a four-carbon molecule, to form a six-carbon molecule, citric acid or citrate.
  - In the mitochondria, pyruvate is turned into acetyl- CoA and 1 NADH is made; double this if you are counting per glucose.
  - The Krebs cycle occurs in the mitochondrial matrix.
  - It begins with acetyl-CoA joining with oxaloacetate to make citric acid and ends with oxaloacetate, 1 ATP, 3 NADH, and 1 FADH2; double this if you are counting per glucose.
  - Citrate gets turned into several other things, and because the cycle begins with a four-carbon molecule, oxaloacetate, it eventually gets turned back into oxaloacetate to maintain the cycle by joining with the next acetyl-CoA coming down the pipeline.
- With each turn of the cycle, three types of energy are produced:
  - 1 ATP
  - 3 NADH
  - 1 FADH2
- To figure out the total number of products per molecule of glucose, we simply double the number of products.

0.15.5 Stage 4: Oxidative Phosphorylation

0.15.6 Electron Transport Chain

- As electrons are removed from a molecule of glucose, they carry much energy that was originally stored in their chemical bonds.
- These electrons are transferred to readied hydrogen carrier molecules.
- In the case of cellular respiration, these charged carriers are the coenzymes NADH and FADH2.
- We now have:
  - 2 NADH molecules from glycolysis
  - 2 NADH from the production of acetyl-CoA
  - 6 NADH from the Krebs cycle
  - 2 FADH2 from the Krebs cycle
- That gives us a total of 12 electron or energy carriers altogether.
- These electron carriers—**NADH and FADH2—"shuttle"** electrons to the electron transport chain, the resulting NAD+ and FADH can be recycled to be used as carriers again, and the hydrogen atoms are split into hydrogen ions and electrons.
- The high-energy electrons from NADH and FADH2 are passed down a series of protein carrier molecules that are embedded in the cristae; thus, it is called the electron transport chain.
- Some of the carrier molecules in the electron transport chain are NADH dehydrogenase and cytochrome C.
- Each carrier molecule hands down the electrons to the next molecule in the chain.
- The electrons travel down the electron transport chain until they reach the final electron acceptor, oxygen. Oxygen combines with these electrons (and some hydrogens) to form water.
- This explains the "aerobic" in aerobic respiration. If oxygen weren't available to accept the electrons, they wouldn't move down the chain at all, thereby shutting down the whole process of electron transport.

0.15.7 Chemiosmosis

- The energy released from the electron transport chain is used to pump hydrogen ions across the inner mitochondrial membrane from the matrix into the inter-membrane space.
- The pumping of hydrogen ions into the inter-membrane space creates a pH gradient, or **proton gradient.**
- The hydrogen ions really want to diffuse back into the matrix. The potential energy established in this gradient is responsible for the production of ATP.
- This pumping of ions and diffusion of ions to create ATP is chemiosmosis
- Overall, this process is called oxidative phosphorylation because when electrons are given up it is called "oxidation" and then ADP is "phosphorylated" to make ATP.
- You're also expected to know the following two things for the AP Biology Exam:
- Every NADH from glycolysis yields 1.5 ATP and all other NADH molecules yield 2.5 ATP.
- Every FADH2 yields 1.5 ATP.

You will also want to make sure you remember the major steps of cell respiration, and the outcome of each steM

0.15.8 Photosynthesis vs. Cell Respiration

- In both cases, ATP production is driven by a proton gradient, and the proton gradient is **created by an electron transport chain.**
- In respiration, protons are pumped from the mitochondrial matrix to the intermembrane space, and they return to the matrix through an ATP synthase down their concentration gradient.
- In photosynthesis, protons are pumped from the stroma into the thylakoids compartment, and they return to the stroma through an ATP synthase down their concentration gradient.
- The **Krebs cycle seeks to oxidize carbohydrates to CO2, while the Calvin cycle seeks to reduce CO2 to carbohydrates.**

0.15.9 Anaerobic Respiration

- When **oxygen is not available,** the anaerobic version of respiration occurs.
  - The electron transport chain stops working, and electron carriers have nowhere to drop their electrons.
  - The mitochondrial production of acetyl- CoA and the Krebs cycle cease too.
  - Glycolysis, however, can continue to run. This means that glucose can be broken down to give net two ATP. Only two instead of 30!
  - Glycolysis also gives two pyruvates and two NADH. The pyruvate and NADH make a deal with each other, and pyruvate helps NADH get recycled back into NAD+ and takes its electrons.
  - The pyruvate turns into either lactic acid (in muscles) or ethanol (in yeast).
  - Since these two things are toxic at high concentrations, this process, called fermentation, is done only in emergencies. Aerobic respiration is a better option
- What types of organisms undergo fermentation?
  - Yeast cells and some bacteria make ethanol and carbon dioxide. Other bacteria produce lactic acid.

0.15.10 Your Muscle Cells Can Ferment

- A **cramp** was possibly the consequence of anaerobic respiration.
- When you exercise, your muscles require a lot of energy.
- To get this energy, they convert enormous amounts of glucose to ATP.
- As you continue to exercise, your body doesn't get enough oxygen to keep up with the demand in your muscles. This creates an oxygen debt.
- Muscles switch over to anaerobic respiration.
- **Pyruvic acid produced** from glycolysis is converted to lactic acid.

0.16 Cell Communication

- Unicellular organisms detect and respond to environmental signals.
- **Taxis** is the movement of an organism in response to a stimulus and can be positive (toward the stimulus) or negative (away from the stimulus).
- Taxes are innate behavioral responses, or instincts. Chemotaxis is movement in response to chemicals.

0.16.1 Signal Transduction Changes In Pathways

- The cells of multi-celled organisms must communicate with one another to coordinate the activities of the organism as a whole.
- Cells communicate through cell-to-cell contact or through cell signaling. Signaling can be **short-range** (affecting only nearby cells) or long-range (affecting cells throughout the organism).
- It can be done by cell junctions or signalling molecules called ligands that bind to receptors and trigger a response by changing the shape of the receptor protein.
- **Signal transduction** is the process by which an external signal is transmitted to the inside of a cell. It usually involves the following three steps:
  1. a signaling molecule binding to a specific receptor
  2. activation of a signal transduction pathway
  3. production of a cellular response
- For signaling molecules that cannot enter the cell, a plasma **membrane receptor is required.**
- Plasma membrane receptors form an important class of integral membrane proteins that transmit signals from the **extracellular space into the cytoplasm**. Each receptor binds a particular molecule in a highly specific way.

0.16.2 There are three classes of membrane receptors.

1. **Ligand-gated ion channels** in the plasma membrane open or close an ion channel upon binding a particular ligand. This channel opens in response to acetylcholine, and a massive influx of sodium depolarises the muscle cell and causes it to contract.
2. **Catalytic (enzyme-linked) receptors** have an enzymatic active site on the cytoplasmic side of the membrane. Enzyme activity is initiated by ligand binding at the extracellular surface.
3. A **G-protein-linked receptor** does not act as an enzyme, but instead will bind a different version of a G-protein (often GTP or GDP) on the intracellular side when a ligand is bound extracellularly. This causes activation of secondary messengers within the cell. One important second messenger is cyclic AMP (cAMP).

- **Signal transduction cascades** are helpful to amplify a signal.

0.16.3 FEEDBACK

- The set of conditions under which living things can successfully survive is called **homeostasis**.
- Your blood glucose levels are regulated by **insulin** and glucagon, two hormones released from your **pancreas**.
- Many of these responses are controlled by **negative or positive** feedback pathways.
- A negative feedback pathway (also called **feedback inhibition)** works by turning itself off using the end product of the pathway. The end product inhibits the process from beginning, thus shutting down the pathway.

A positive feedback pathway also involves an end product playing a role, but instead of inhibiting the pathway, it further stimulates it.

0.17 The cell cycle

- Every cell has a life cycle—the period from the beginning of one division to the beginning of the next.
- The cell's life cycle is known as the **cell cycle.**
- The cell cycle is divided into two periods: **interphase and mitosis.**

0.18 Interphase: the growing phase

- Interphase is the time span from one cell division to another.
- The Three Stages of Interphase Interphase can be divided into three stages: G1, S, G2.
- The most important phase is the **S phase**. That's when the cell **replicates its genetic mater**ial.
- During **interphase**, every single chromosome in the nucleus is duplicated.
- These identical strands of DNA are now called sister chromatids.
- The chromatids are held together by a structure called the **centromere**.
- You can think of each chromatid as a chromosome, but because they remain attached, they are called chromatids instead.
- To be called a chromosome, each needs to have its **own centromere.**
- Once the chromatids separate, they will be full-fledged **chromosomes**.

0.18.1 Cell Cycle Regulation

- G1 and G2- During these stages, the cell performs **metabolic reactions and produces organelles, proteins, and enzymes.**
- G stands for "**gap**," but we can also associate it with "growth."
- These three phases are highly regulated by checkpoints and special proteins called cyclins and cyclin-dependent kinases (**CDKs**).
- Cell cycle checkpoints are control mechanisms that make sure cell division is happening properly in eukaryotic cells.
- In eukaryotes, checkpoint pathways function mainly at phase boundaries (such as the G1/S transition and the G2/M transition).
- When damaged DNA is found, checkpoints are activated and cell cycle progression stops. The cell uses the extra time to repair damage in DNA. If the DNA damage is so extensive that it cannot be repaired, the cell can undergo apoptosis, or programmed cell death.

- Cell cycle checkpoints control cell cycle progression by regulating two families of proteins:
  - cyclin-dependent kinases (CDKs)
  - cyclins.
- To induce cell cycle progression, an inactive CDK binds a regulatory cyclin. Once together, the complex is activated, can affect many proteins in the cell, and causes the cell cycle to continue.
- **To inhibit cell cycle progression, CDKs and cyclins are kept separate**. CDKs and cyclins were first studied in yeast, unicellular eukaryotic fungi.

0.18.2 Cancer

- Cancer occurs when normal cells start behaving and growing very abnormally and spread to other parts of the body.
- Mutated genes that induce cancer are called **oncogenes**.
- They are genes that can convert normal cells into cancerous cell healthy version is called a **proto-oncogene.**
- Tumour suppressor genes produce proteins that prevent the conversion of normal cells into cancer cells. They can detect damage to the cell and work with CDK/cyclin complexes to stop cell growth until the damage can be repaired.
- They can also trigger apoptosis if the damage is too severe to be repaired.

0.19 Mitosis: the dance of the chromosomes

- Mitosis, or cellular division, occurs in four stages:
- prophase, metaphase, anaphase, and telophase.
- During **prophase**, the nuclear envelope disappears and chromosomes condense.
- Next is **metaphase**, when chromosomes align at the metaphase plate and mitotic spindles attach to kinetochores.
- In anaphase, chromosomes are pulled away from the center. **Telophase** terminates mitosis, and the two new nuclei form.
- The process of cytokinesis, which occurs during telophase, ends mitosis, as the cytoplasm and plasma membranes pinch to form two distinct, identical daughter cells.
- **Interphase** Once daughter cells are produced, they reenter the initial phase—interphase —and the whole process starts over. The cell goes back to its original state. Once again, the chromosomes decondense and become invisible, and the genetic material is called chromatin again.

0.19.1 Purpose of Mitosis

- Mitosis achieves two things:
- The production of daughter cells that are **identical** copies of the parent cell **maintaining the proper number of chromosomes** from generation to generation
- The impetus to divide occurs because an organism needs to grow, a tissue needs repair, or asexual reproduction must take place.

0.20 Haploids Versus Diploids

- A cell that has two sets of chromosomes is a diploid cell.
- The chromosome number is given as "2n." That means we have two copies of each chromosome.
- If a cell has only one set of chromosomes, we call it a haploid cell. This kind of cell is given the symbol n.
- The duplicate versions of each chromosome are called homologous chromosomes.
- The homologous chromosomes that make up each pair are similar in size and shape and contain the same genes in the same locations

0.20.1 Gametes

- Sex cells are **haploid**.
- A parent will contribute a gamete with one set that will be paired with the set from the other parent to produce a new diploid cell, or zygote.

0.21 Gregor Mendel: The Father of Genetics

- Genetics was discovered by the monk **Gregor Mendel**
- Traits are influenced by one or more of your **genes**.
- The position of a gene on a chromosome is called a **locus**.
- Diploid organisms usually have two copies of each gene, one on each **homologous chromosome.**
- Homologous chromosomes are two copies or versions of the same chromosome in a diploid cell or organism.
- Humans have 23 pairs of homologous chromosomes.
- Homologous chromosomes are the same size and shape, and contain the same genes. However, they can contain different versions(alleles) of those genes, and thus have different genetic sequences.
- When an organism has two identical alleles for a given trait, the organism is **homozygous**.
- If an organism has two different alleles for a given trait, the organism is **heterozygous**.
- When discussing the physical appearance of an organism, we refer to its **phenotype**.
- The **genotype** tells us which alleles the organism possesses.
- The **dominant** allele receives a capital letter and the **recessive** allele receives a lowercase of the same letter.
- Label each generation in the cross.
  - The first generation in an experiment is always called the **parent**, or P generation.
  - The offspring of the P generation are called the first filial, or **F1** generation. Members of the next generation, the grandchildren, are called the F2 generation.
- The three principles of genetics: the Law of Dominance, the Law of Segregation, and the Law of Independent Assortment.

0.21.1 The Law of Dominance

- Mendel crossed two true-breeding plants with contrasting traits: tall pea plants and short pea plants.
- To his surprise, when Mendel mated these plants, the characteristics didn't blend to produce plants of average height. Instead, all the offspring were tall.
- A **monohybrid** cross occurs when two individuals are crossed and one gene is being studied. A simple way to represent a monohybrid cross is to set up a Punnett square. Punnett squares are used to predict the results of a cross.

0.21.2 The Law of Segregation

Next, Mendel took the offspring and self-pollinated them.

- Here's a summary of the results: The ratio of phenotypes is 3:1 (three tallUnknown Node :: textDirective short). The ratio of genotypes is 1:2:1 (one TTUnknown Node :: textDirective

  TtUnknown Node :: textDirective tt).

0.21.3 The Law of Independent Assortment

- So far, we have looked at only one trait: tall versus short.
- What happens when we study two traits at the same time? Each allele of the two traits will get segregated into two gametes, but how one trait gets split up into gametes has no bearing on how the other trait gets split up.

0.21.4 Dihybrid Cross

- Different genes assort independently into gametes. A **dihybrid** cross is just like the monohybrid, but it studies how two genes are passed on to offspring.

0.21.5 Rules of Probability

- A better method for predicting the likelihood of certain results from a dihybrid cross is to apply the **Rules of Probability**.
- To determine the probability that two or more independent events will occur simultaneously, one can simply calculate the product of the probability that each will occur independently. This is called the **Product Rule.**
- To determine the likelihood that EITHER event occurs, but not both, use another rule called the Sum Rule.
- **Product Rule**: If A and B are independent, then: P(A and B) = P(A) times P(B) **Sum Rule**: If A and B are mutually exclusive, then: P(A or B) = P(A) + P(B)
- To find the probability of having a tall, yellow plant, simply multiply the probabilities of each event. If the probability of being tall is 3/4 and the probability of being yellow is 1/4, then the probability of being tall and yellow is 3/16 .

0.21.6 SUMMARY OF MENDEL'S LAWS

- Law of **Dominance**: One trait masks the effects of another trait.
- Law of **Segregation**: Each gamete gets only one of the copies of each gene.
- Law of **Independent Assortment:** Each pair of homologous chromosomes splits independently, so the alleles of different genes can mix and match.
- Suppose we want to know if a tall plant is homozygous (TT) or heterozygous (Tt). Its physical appearance doesn't necessarily tell us about its genetic makeup. The only way to determine its genotype is to cross the plant with a recessive, short plant, tt. This is known as a test cross.

0.22 Non-Mendelian Genetics Sex-Linked Traits

0.22.1 Linked Genes

- Sometimes genes on the same chromosome stay together during assortment and move as a group.
- The group of genes is considered linked and tends to be inherited together. For example, the genes for flower color and pollen shape are linked on the same chromosomes and show up together.
- Since linked genes are found on the same chromosome, they cannot segregate independently.
- This **violates the Law of Independent Assortment.**
- The offspring formed from recombination events are called recombinants.
- The percentage of recombination (recombination frequency) can be determined by adding up the recombinants and dividing by the total number of offspring
- The frequency of crossing-over between any two linked alleles is proportional to the distance between them. This finding led to **recombination mapping**— mapping of linkage groups with each map unit being equal to 1 percent recombination.
- For example, if two linked genes, A and B, recombine with a frequency of 15 percent, and B and C recombine with a frequency of 9 percent, and A and C recombine with a frequency of 24 percent, what is the sequence and the distance between them?
- A-B is 15 units
- B-C is 9 units
- Total 24 units

0.22.2 Sex-linked traits

- Humans contain 23 pairs of chromosomes. Twenty- two of the pairs of chromosomes are called **autosomes**.
- They code for many different traits.
- The other pair contains the sex chromosomes. This pair determines the sex of an individual.
- A female has two X chromosomes. A male has one X and one Y chromosome.
- Some traits, such as color **blindness and hemophilia,** are carried on sex chromosomes.These are called **sex-linked traits.**
- Most sex- linked traits are found on the **X** chromosome and are more properly referred to as "X-linked."
- Since males have one X and one Y chromosome, what happens if a male has an X-chromosome with the color blindness allele? Unfortunately, he'll express the sex-linked trait, even if it is recessive.
- However, if a female has only one color blind-X chromosome, she won't express a recessive sex-linked trait. For her to express the trait, she has to inherit two color blind-X chromosomes.
- A female with one color blind-X is called a **carrier**. Although she does not exhibit the trait, she can still pass it on to her children.
- You can also use the Punnett square to figure out the results of sex-linked traits.

0.22.3 Barr Bodies

- A look at the cell nucleus of normal females will reveal a dark-staining body known as a Barr body.
- A **Barr body** is an X chromosome that is condensed and visible. In every female cell, one X chromosome is activated and the other X chromosome is deactivated during embryonic development.
- The X chromosome destined to be inactivated is randomly chosen in each cell.
- Therefore, in every tissue in the adult female, one X chromosome remains condensed and inactive. However, this X chromosome is replicated and passed on to a daughter cell.
- X-inactivation is the reason it is okay that females have two X chromosomes and males have only one. After X-inactivation, it is like everyone has one copy.

0.22.4 Other Inheritance Patterns

- **Incomplete dominance (**blending inheritance): In some cases, the traits will blend. For example, if you cross a white snapdragon plant (genotype WW) with a red snapdragon plant (RR), the resulting progeny will be pink (RW). In other words, neither color is dominant over the other.
- **Codominance**: Sometimes you'll see an equal expression of both alleles. For example, an individual can have an AB blood type. In this case, each allele is equally expressed.
- **Polygenic inheritance**: In some cases, a trait results from the interaction of many genes. Each gene will have a small effect on a particular trait.
- **Non-nuclear inheritance:** Apart from the genetic material held in the nucleus, there is also genetic material in the mitochondria. The mitochondria are always provided by the egg during sexual reproduction, so mitochondrial inheritance is always through the maternal line, not the male line. In plants the mitochondria are provided by the ovule and are maternally inherited.

0.22.5 Pedigrees

- One way to study genetic inheritance is by looking at a special family tree called a **pedigree**.
- A pedigree shows which family members have a particular trait and it can help determine if a trait is recessive or dominant and if it is sex-linked.
- Traits that skip generations are usually **recessive**.
- Traits that appear more in one sex than the other are usually **sex-linked.**
- In a pedigree chart, the males are squares and the females are circles.

0.23 Environmental Effect on Traits

- Changes in genotypes can result in changes in **phenotype**, but environmental factors also influence many traits, directly and indirectly.
- Furthermore, an organism's adaptation to the local environment reflects a flexible response of its genome
- Phenotypic plasticity occurs if two individuals with the same genotype have different phenotypes since they are in different environments.

0.24 An Overview of Meiosis

- Meiosis is the production of **gametes**.
- Meiosis is limited to sex cells in special sex organs called gonads.
- In males, the **gonads** are the testes, while in females they are the **ovaries**.
- The special cells in these organs—also known as germ cells—produce haploid cells (n), and they combine to restore the **diploid** (2n) number during **fertilization**. female gamete (n) + male gamete (n) = zygote (2n)

Meiosis is likely to produce sorts of **variations** than is mitosis, which therefore confers selective advantage on sexually reproducing organisms.

0.24.1 A Closer Look at Meiosis

- Meiosis actually involves two rounds of cell division: meiosis I and meiosis II.
- Before meiosis begins, the diploid cell goes through interphase. Just as in mitosis, double-stranded chromosomes are formed during S phase.
- **Meiosis I**
  - Meiosis I consists of four stages: **prophase I, metaphase I, anaphase I, and telophase I.**
  - Meiosis I ensures that each gamete receives a haploid (1n) set of chromosomes.
- **Prophase I**
  - As in mitosis, the nuclear membrane disappears, the chromosomes become visible, and the centrioles move to opposite poles of the nucleus.
  - The major difference involves the movement of the chromosomes. In meiosis, the chromosomes line up side-by-side with their counterparts (**homologs**). This event is known as synapsis.
  - **Synapsis** involves two sets of chromosomes that come together to form a tetrad (a bivalent). A tetrad consists of four chromatids. **Synapsis** is followed by crossing-over, the exchange of segments between homologous chromosomes.
  - What's unique in prophase I is that pieces of chromosomes are exchanged between homologous partners. This is one of the ways organisms produce genetic variation.
- **Metaphase I**
  - As in mitosis, the chromosome pairs—now called tetrads—line up at the **metaphase plate**.
  - By contrast, you'll recall that in regular metaphase, the chromosomes line up individually.
  - One important concept to note is that the alignment during metaphase is random, so the copy of each chromosome that ends up in a daughter cell is random.
- **Anaphase I**
  - During anaphase I, each pair of chromatids within a tetrad moves to opposite poles. The homologs will separate with their centromeres intact.
  - The chromosomes now move to their respective poles.
- **Telophase I**
- During telophase I, the nuclear membrane forms around each set of chromosomes.
- Finally, the cells undergo cytokinesis, leaving us with two daughter cells.
- **Meiosis II**

  - The purpose of the second meiotic division is to separate sister chromatids

- During **prophase II**, chromosomes once again condense and become visible.
- In **metaphase II,** chromosomes move toward the metaphase plate. This time they line up single file, not as pairs.
- During **anaphase II,** chromatids of each chromosome split at the centromere, and each chromatid is pulled to opposite ends of the cell.
- At **telophase II,** a nuclear membrane forms around each set of chromosomes and a total of four haploid cells are produced.

0.24.2 Gametogenesis

- Meiosis is also known as **gametogenesis**.
- If sperm cells are produced, then meiosis is called **spermatogenesis**.
- During spermatogenesis, four sperm cells are produced for each diploid cell.
- If an egg cell or an ovum is produced, this process is called **oogenesis**.
- Oogenesis produces only one ovum, not four. The other three cells, called polar bodies, get only a tiny amount of cytoplasm and eventually degenerate since the female wants to conserve as much cytoplasm as possible for the surviving gamete, the ovum.

0.24.3 Meiotic Errors

- **Nondisjunction**—chromosomes failed to separate properly during meiosis.
- This error, which produces the wrong number of chromosomes in a cell, usually results in miscarriage or significant genetic defects.
- Individuals with **Down syndrome** have three—instead of two—copies of the 21st chromosome.
- Nondisjunction can occur in **anaphase I (**meaning chromosomes don't separate when they should), or in anaphase II (meaning chromatids don't separate).
- Either one can lead to **aneuploidy**, or the presence of an abnormal number of chromosomes.

0.25 DNA: The Blueprint of Life

- **DNA** is made up of repeated subunits of nucleotides. Each nucleotide has a five-carbon sugar, a phosphate, and a nitrogenous base.
- The name of the pentagon-shaped sugar in DNA is **deoxyribose**. Hence, the name deoxyribonucleic acid. Notice that the sugar is linked to two things: a phosphate and a nitrogenous base. A nucleotide can have one of four different nitrogenous bases:
  - adenine—a purine (double-ringed)
  - guanine—a purine (double-ringed)
  - cytosine—a pyrimidine (single-ringed)
  - thymine—a pyrimidine (single-ringed)
- Prokaryotes and eukaryotes can also contain plasmids, which are small double-stranded, circular DNA molecules. The nucleotides can link up in a long chain to form a single strand of DNA
- The nucleotides themselves are linked together by **phosphate** bonds between the sugars and the phosphates. This is called the sugar-phosphate backbone of DNA and it serves as a scaffold for the bases.

0.25.1 Two DNA Strands

- Each DNA molecule consists of two strands that wrap around each other to form a long, twisted ladder called a **double helix**. The structure of DNA was brilliantly deduced in 1953 by three scientists: Watson, Crick, and Franklin.
  - Adenine pairs up with thymine (A–T) by forming two hydrogen bonds.
  - Cytosine pairs up with guanine (G–C) by forming three hydrogen bonds.
- This predictable matching is is known as base pairing. The two strands are said to be **complementary**.
  - The 5 end has a phosphate group, and the 3 end has an OH, or "hydroxyl," group.
  - The 5 end of one strand is always opposite to the 3 end of the other strand. The strands are therefore said to be antiparallel.
- The DNA strands are linked by **hydrogen** bonds.

0.26 Genome Structure

- All of the DNA for a species is called its **genome**.
- Each separate chunk of DNA in a genome is called a **chromosome**.
- DNA is wrapped around proteins called histones, and then the histones are bunched together in groups called a **nucleosome**.
- When the genetic material is in a loose form in the nucleus, it is called **euchromatin**, and its genes are active, or available for transcription.
- When the genetic material is fully condensed into coils, it is called heterochromatin, and its genes are generally inactive.

0.27 DNA Replication

- This copying of DNA is known as **DNA replication**.
  - The first step in replication is to unwind the double helix by breaking the hydrogen bonds. This is accomplished by an enzyme called **helicase**.
  - The exposed DNA strands now form a **y**-shaped replication fork.
  - Each strand can serve as a **template** for the synthesis of another strand.
  - DNA replication begins at specific sites called **origins** of replication.
  - DNA helix twists and rotates during DNA replication, another class of enzymes, called DNA **topoisomerases**, cuts, and rejoins the helix to prevent tangling.
  - The enzyme that performs the actual addition of nucleotides to the freshly built strand is DNA polymerase. But DNA polymerase can add nucleotides only to the 3 end of an existing strand.
  - To start off replication, an enzyme called RNA **primase** adds a short strand of RNA nucleotides called an RNA primer.
  - After replication, the primer is degraded by enzymes and replaced with DNA so that the final strand contains only DNA.
  - During DNA replication, one DNA strand is called the leading strand, and it is made continuously. The nucleotides are steadily added one after the other by DNA polymerase.
  - The other strand—the lagging strand—is made discontinuously. Unlike the leading strand, the lagging strand is made in pieces of nucleotides known as **Okazaki fragments.**

- Nucleotides are added only in the 5 to 3 direction since nucleotides can be added only to the 3 end of the growing chain.
- However, when the double-helix is "unzipped," one of the two strands is oriented in the opposite direction—3 to 5.
- Because DNA polymerase doesn't work in this direction, the strand needs to be built in pieces.
- The lagging strand is built in the opposite direction of the way the helix is opening, so it can build only until it hits a previously built stretch. Once the helix unwinds a bit more, it can build another Okazaki fragment.
- These fragments are eventually linked together by the enzyme DNA **ligase** to produce a continuous strand.
- Finally, hydrogen bonds form between the new base pairs, leaving two identical copies of the original DNA molecule.
- When DNA is replicated, we don't end up with two entirely new molecules.
- Each new molecule has half of the original molecule. Because DNA replicates in a way that conserves half of the original molecule in each of the two new ones, it is said to be **semiconservative**.
- The bits of unimportant DNA are at the ends of a molecule. These ends are called telomeres.
- Many enzymes and proteins are involved in DNA replication.

The ones you'll need to know for the AP Biology Exam are DNA helicase, DNA polymerase, DNA ligase, topoisomerase, and RNA primase:

- **Helicase** unwinds our double helix into two strands.
- **DNA Polymerase** adds nucleotides to an existing strand.
- **Ligase** brings together the Okazaki fragments.
- **Topoisomerase** cuts and rejoins the helix.
- **RNA** primase catalyzes the synthesis of RNA primers.

0.27.1 Central Dogma

- The first step of DNA expression is to turn it into RNA. The RNA is then sent out into the cell and often gets turned into a protein.
- These proteins, in turn, regulate almost everything that occurs in the cell.
- The process of making an RNA from DNA is called **transcription**, and the process of making a protein from an RNA is called **translation**.

DNA - mRNA via transcription - protein via translation

0.28 RNA

1.RNA is single-stranded.

1. The 5-carbon sugar in RNA is ribose instead of deoxyribose.
2. Uracil replaces thymine as adenine's partner.

- Messenger RNA (**mRNA**) is a temporary RNA version of a DNA recipe that gets sent to the ribosome.
- Ribosomal RNA (**rRNA**), makes up part of the ribosomes.
- Transfer RNA (**tRNA**) brings amino acids to the ribosomes. It brings the brings a specific amino acid into place at the appropriate time by matching anticodons to codons. It does by reading the message carried by the mRNA.

0.28.1 Transcription

- Transcription involves making an RNA copy of a bit of DNA code.
- In replication we end up with a complete copy of the cell's DNA, in transcription we end up with only a tiny specific section copied into an mRNA.
- Transcription begins at special sequences of the DNA strand called **promoters**.
- The official starting point is called the start site.
- We copy only one of the two DNA strands.
- The strand that serves as the template is known as the **antisense** strand.
- The other strand that lies dormant is the sense strand, or the coding strand.
- RNA polymerase builds RNA by adding nucleotides only to the 3 side, therefore building a new molecule from 5 to 3

0.28.2 RNA Processing

- The regions that express the code are **exons**.
- The noncoding regions in the mRNA are **introns**.
- Prokaryotes will transcribe a recipe that can be used to make several proteins. This is called a **polycistronic transcript.**
- Eukaryotes tend to have one gene that gets transcribed to one mRNA and translated into one protein. Our transcripts are **monocistronic**.
- The introns must be removed before the mRNA leaves the nucleus. This process, called splicing, is accomplished by an RNA-protein complex called a **spliceosome**.
- In addition, a poly(A) tail is added to the 3 end
- And, a 5 GTP cap is added to the 5 end.

0.29 Translation

- mRNA —¿ protein
- Process occurs on ribosomes in **cytoplasm** and on the rough endoplasmic reticulum
- 3 nucleotides is called a codon. Each codon corresponds to a particular amino acid.
- One end of the tRNA carries an amino acid. The other end, called an anticodon, has three nitrogenous bases that can complementarily base pair with the codon in the mRNA.
- The third position is said to experience wobble pairing. Things that don't normally bind will pair up, like guanine and uracil.
- Translation also involves three phases: initiation, elongation, and termination.

0.29.1 Initiation

- It begins when a **ribosome attaches to the mRNA.**
- Ribosomes contain three binding sites: an A site, a P site, and an E site. The mRNA will shuffle through from A to P to E. As the mRNA codons are read, the polypeptide will be built.
- The start codon is **A–U–G,** which codes for the amino acid methionine.
- The tRNA with the complementary anticodon, U– A–C, is methionine's personal shuttle; when the AUG is read on the mRNA, methionine is delivered to the ribosome.

0.29.2 Elongation

- Addition of amino acids is called elongation and when many amino acids link up, a **polypeptide is formed.**

0.29.3 Termination

The synthesis of a polypeptide is ended by **stop codons**. There are three that serve as a stop codon. Termination occurs when the ribosome runs into one of these three stop codons.

0.30 Regulation of Zene Expression and Cell Specialization

- Regulation of gene expression can occur at different times. The largest point is before transcription, or pre-transcriptional regulation.
- Transcription factors can encourage or inhibit this from happening.
- Sometimes changes to the packaging of DNA will alter the ability of the transcription machinery to access a gene, this is called epigenetic changes.
- In bacteria, a cluster of genes can be under the control of a single promoter; these functioning units of DNA are called operons.
- The operon consists of four major parts:

structural genes, promoter genes, the operator, and the regulatory gene:

- **Structural genes** code for enzymes needed in a chemical reaction. These genes will be transcribed at the same time to produce particular enzymes.
- The **promoter gene** is the region where the RNA polymerase binds to begin transcription.
- The **operator** is a region that controls whether transcription will occur; this is where the repressor binds.
- The **regulatory gene** codes for a specific regulatory protein called the repressor. The repressor is capable of attaching to the operator and blocking transcription.
- **Post-transcriptional regulation** occurs when the cell creates an RNA, but then decides that it should not be translated into a protein. This is where RNAi comes into play.
- **RNAi** molecules can bind to an RNA via complementary base pairing. This creates a double-stranded RNA
- **Post-translational regulation** can also occur if a cell has already made a protein, but doesn't yet need to use it.

0.30.1 Gene Regulation in Embryonic Development

- The cell changes shape and organization many times by going through a succession of stages. This process is called **morphogenesis**.
- Fertilization triggers the zygote to go through a series of cell divisions.
- The early genes that turn certain cells in the early embryo into future-this or future-that are called homeotic genes. A subset of homeotic genes are called **Hox genes.**

0.31 Mutations

- A **mutation** is an error in the genetic code.
- Mutations can occur because DNA is damaged caused by chemicals or radiation and cannot be repaired or because DNA damage is repaired incorrectly.

0.31.1 Base Substitution

- **Base substitution** (point) mutations result when a single nucleotide base is substituted for another. There are three different types of point mutations:
- **Nonsense mutations** cause the original codon to become a stop codon, which results in early termination of protein synthesis.
- **Missense mutations** cause the original codon to be altered and produce a different amino acid.
- **Silent mutations** happen when a codon that codes for the same amino acid is created and therefore does not change the corresponding protein sequence.

0.31.2 Gene Rearrangements

1. **Insertions and deletions** result in the gain or loss, respectively, of DNA or a gene. Introduction or deletion of bases often results in a change in the sequence of codons used by the ribosome (called a frameshift mutation) to synthesize a polyprotein.
2. **Duplications** can result in an extra copy of genes and are usually caused by unequal crossing-over during meiosis or chromosome rearrangements. This may cause a new trait
3. **Inversions** can result when changes occur in the orientation of chromosomal regions
4. **Translocations** occur when two different chromosomes break and rejoin in a way that causes the DNA sequence or gene to be lost, repeated, or interrupted.
5. **Transposons** are gene segments that can cut/paste themselves throughout the genome. Its presence can interrupt a gene and cause errors in gene expression.

- **Bacteria are prokaryotes** that come in many shapes and sizes.
- Bacteria divide by **fission**; however, this does not increase their genetic diversity. Instead, they can perform conjugation with other bacterial cells and swap some of their DNA.
- Viruses are nonliving agents capable of infecting cells since they require a host cell's machinery in order to replicate.
- A virus has two main components:
  - a protein shell (the capsid)
  - genetic material made of DNA or RNA.

    The thing infected by a virus is called a host.

- Bacteriophages undergo two different types of replication cycles, **the lytic cycle and the lysogenic cycle.**
- In the lytic cycle, the virus immediately starts using the host cell's machinery to replicate the genetic material and create more capsid proteins.
- The transfer of DNA between bacterial cells using a lysogenic virus is called **transduction**.
- Viruses with a lipid envelope are called enveloped viruses.
- Retroviruses like HIV are RNA viruses that use an enzyme called reverse **transcriptase** to convert their RNA genomes into DNA so that they can be inserted into a host genome.

0.32 Biotechnology

- **Recombinant DNA** is generated by combining DNA from multiple sources to create a unique DNA molecule that is not found in nature.
- A common application of recombinant DNA technology is the introduction of a eukaryotic gene of interest into a bacterium for production for research and to cure diseases
- This technology that produces new organisms or products by transferring genes between cells is called **genetic engineering.**

0.32.1 Polymerase Chain Reaction (PCR)

- PCR is a laboratory technique that is used to create billions of **identical copies of genes** within hours.
- The process of creating many copies of genes is known as **amplification**.
- The process of giving bacteria foreign DNA is called **transformation**.
- A technique that is alike, is transfection, which is putting a plasmid into a eukaryotic cell, rather than a bacteria cell.
- DNA fragments can be separated according to their molecular weight and charge with gel electrophoresis. Since DNA and RNA are negatively charged, they go through a gel toward the positive pole of the electrical field.
- When restriction fragments between individuals of the same species are compared, the fragments differ in length because of polymorphisms, which are differences in DNA sequences.
- These fragments are called restriction fragment length **polymorphisms**, or **RFLPs**.
- DNA sequencing allows scientists to determine the order of nucleotides in a DNA molecule. Scientists could design their own DNA plasmid and use it to study a gene of interest.

0.33 Natural Selection

- **Evolution** is a change in a population over time.
- Natural selection is defined in terms of populations but occurs in terms of individuals.
- Much of what we know about evolution is based on the work of **Charles Darwin**

0.33.1 Darwin's observations:

- Each species produces more offspring than can survive.
- These offspring compete with one another for the limited resources available to them.
- Organisms in every population vary.
- **Evolutionary fitness** is measured by reproductive success. The fittest offspring, or those with the most favorable traits, are the most likely to survive and therefore produce a second generation.
- These are the traits most likely to pass to subsequent generations. Fitness varies based on biotic and abiotic factors; different genetic variations can be selected for in different generations.

0.33.2 Lamarck and the Long Necks

- A theory of evolution in Darwin's day was proposed by Jean-**Baptiste de Lamarck.**
- He proposed that acquired traits were inherited and passed on to offspring.

0.33.3 Evidence for Evolution

- **Paleontology**: paleontology revealed the various organisms and the major lines of evolution. Fossils can be dated by:

i. The age of the rocks where a fossil is found
ii. The rate of decay of isotopes including carbon-14
iii. Geographical data

- **Biogeography**, or the study of the distribution of flora (plants) and fauna (animals) in the environment: scientists found related species in widely separated regions of the world.
- **Embryology**, or the study of development of an organism: All the vertebrates—including fish, amphibians, reptiles, birds, and even mammals such as humans—show fishlike features called gill slits.
- **Morphological homologies**, or the study of the anatomy of various animals: scientists discovered that some animals have similar structures that serve different functions. Homologous structures, also point to a common ancestor. Analogous structures evolved totally independently of one another.
- **Molecular Biology**: The most compelling proof of all is the similarity at the molecular level.
- **Continuing Evolution**: Evolution is constantly occurring. We can see small changes in DNA and changes in the fossil record consistently

0.34 Common Ancestry

- Some original life-form is the common ancestor to all life.
- Charts called **phylogenetic trees, or cladograms,** are used to study relationships between organisms.
- Phylogenetic trees are built using data from the fossil record or molecular record. Cladograms are often drawn with even spacing between species, but phylogenetic trees are often drawn with different distances between species and as a result they look more like a tree with uneven branches.
- They always begin with the common ancestor and then branch out. Anytime there is a fork in the road, it is called a common ancestor node

0.35 Genetic Variability

- The differences in people are known as **genetic variability**.
- Natural selection occurs only if some individuals have more evolutionary fitness and can be selected. The more variations there are among a population, the more likely that a trait will exist that might be the perfect lifesaver.
- Genetic variation is the very foundation of evolution

0.35.1 The Peppered Moths

- Exactly half of them were dark and carried alleles for dark coloring. The other half were light and carried alleles for light coloring. This 1:1 ratio of phenotypes was observed until air pollution, due primarily to the burning of coal, changed the environment.
- The gene pool reached 90 percent dark alleles and only 10 percent light alleles. This occurred because the light moths didn't stand a chance in an environment where they were so easy to spot. The dark moths, on the other hand, multiplied just as fast as they could.

0.36 Causes of Evolution

- Natural selection requires genetic variation and an environmental pressure.
- **Biotic and abiotic** factors can affect the direction of evolution.
- As long as a mutation does not kill an organism before it reproduces it may be passed on to the next generation.
- Survival of the fittest is the name of the game, and any trait that causes an individual to reproduce better gives that individual evolutionary fitness
- Females choose to mate with males that have a large and beautiful tail. This is an example of sexual selection.
- Genetic drift is something that causes a change in the genetics of a population, but it is not natural selection. Instead. It is also called the bottleneck effect or the founder effect, this occurs when only a few individuals are left to mate and regrow a population.
- **Gene flow** can occur between different populations of the same species if individuals migrate.
- The situation with our moths is an example of directional selection.
- Two other types of selection are **stabilizing selection and disruptive selection**. Stabilizing selection means that organisms in a population with extreme traits are eliminated.
- Another type of selection to be aware of is artificial selection. This is a type of selection where humans directly affect variation in other species.

0.37 Species Population

- In order to become different species, they would have to become reproductively isolated from each other.
- With different variation and different environmental pressures, they could each change in different ways and no longer be able to mate. This is called divergent evolution.
- Divergent evolution that occurs quickly after a period of stasis is called punctuated equilibrium.
- Pre-zygotic barriers prevent fertilization.
- A post-zygotic barrier is related to the inability of a hybrid organism to produce offspring.

- Convergent evolution is the process by which two unrelated and dissimilar species come to have similar traits, often because they have been exposed to similar selective pressures.
- There are two types of speciation:
- Allopatric speciation and sympatric speciation.
- Allopatric speciation simply means that a population becomes separated from the rest of the species by a geographic barrier so the two populations can't interbreed.

0.38 Genetics

- Mendel's laws can extend to the population level.
- The Hardy-Weinberg law states that even with all the shuffling of genes that goes on, the relative frequencies of genotypes in a population are constant over time.
- p2 + 2pq + q2 = 1
- In this equation, p2 represents the homozygous dominants, 2pq represents the heterozygotes, and q2 represents the homozygous recessives.
- It is important to understand the consequences on the population if any of the five conditions are not met:
    1. If the population is small, the population will be more susceptible to random environmental impact than if the population is large.
    2. If mutations are present in a population, new alleles will be introduced into the population and hence genetic equilibrium will be disturbed.
    3. If immigration or emigration is present, species entering or leaving a population will bring or remove alleles with them.
    4. If there is non-random mating, individuals will be selective in how they pick their mating partners based on a trait or traits.
    5. If there is natural selection, organisms better adapted to their environment will be more likely to survive and reproduce, and thus their alleles will be preferentially propagated to the next generation.

0.39 Origins of Life on Earth

- Two scientists, **Alexander Oparin and J. B. S. Haldane,** proposed that the primitive atmosphere contained mostly inorganic molecules and was rich in the following gases:
- methane (CH4),ammonia (NH3), hydrogen (H2), and water (H2O).
- There was almost no free oxygen (O2) in this early atmosphere.
- Stanley Miller and Harold Urey simulated the conditions of primitive Earth in a laboratory. They put the gases theorized to be abundant in the early atmosphere into a flask, struck them with electrical charges in order to mimic lightning, and organic compounds similar to amino acids appeared.
- The original life-forms were simply molecules of RNA. This is called the RNA-world hypothesis.

0.40 Interacting with the Environment Behaviour

- **Endotherms** are animals that generate their own body heat through metabolism. Ectotherms lack an internal mechanism to control body temperature.
- **Instinct** is an inborn, unlearned behavior.
- Another form of behavior is learning. Learning refers to a change in a behavior brought about by an experience

- If the mother is absent, the offspring will accept the first moving object they see as their mother. This process is known as imprinting.
- While there are different types of imprinting, including parent, sexual, and song imprinting, they all occur during a critical period—a window of time when the animal is sensitive to certain aspects of the environment.
- **Habituation** is another form of learning. It occurs when an animal learns not to respond to a stimulus.
- Roosters do have internal alarm clocks. Plants have them as well. These internal clocks, or cycles, are known as circadian rhythms.

0.41 How Animals Communicate

- Pheromones, are chemical signals between members of the same species that stimulate olfactory receptors and ultimately affect behavior.
- **Agonistic behavior** is aggressive behavior that occurs as a result of competition for food or other resources.
- **Dominance hierarchies** (pecking orders) occur when members in a group have established which members are the most dominant.
- Territoriality is a common behavior when food and nesting sites are in short supply.
- **Altruistic behavior** is defined as unselfish behavior that benefits another organism in the group at the individual's expense because it advances the genes of the group.

Many organisms that coexist exhibit some type of symbiotic relationship
The basic types of symbiotic relationships:

1. **Mutualism**—in which both organisms win (for example, the lichen components)
2. **Commensalism**—in which one organism lives off another with no harm to the host organism (for example, the remora)
3. Parasitism—in which the organism actually harms its host

0.42 Plant Behavior

- Plants flower in response to changes in the amount of daylight and darkness they receive. This is called photoperiodism
- A tropism is a turning in response to a stimulus.
- There are three basic tropisms in plants.

1. **Phototropism** refers to the way plants respond to sunlight—for example, bending toward light.
2. Gravitropism refers to the way plants respond to gravity. Stems exhibit negative gravitropism (they grow up, away from the pull of gravity), whereas roots exhibit positive gravitropism (they grow downward into the earth).
3. **Thigmotropism** refers to the way plants respond to touch. For example, ivy grows around a post or trellis.

0.43 Ecology

- The study of interactions between living things and their environments is known as ecology.
- Biosphere: The entire part of the Earth where living things exist.
- **Ecosystem**: The interaction of living and nonliving things
- Community: A group of populations interacting in the same area Population: A group of individuals that belong to the same species and that are interbreeding

There are two types of primary productivity:

1. The gross productivity from photosynthesis cannot be measured because cell respiration is occurring at the same time.
2. Net productivity measures organic materials that are left over after photosynthetic organisms have taken care of their own cellular energy needs.

- Producers make their own food.
- **Primary consumers** (herbivores) eat producers.
- **Secondary consumers** (carnivores and omnivores) eat producers and primary consumers.
- **Tertiary consumers** eat all of the above. Decomposers break things down.
- Sometimes one organism is particularly important to an ecosystem. Species like this are called keystone species.
- In a food chain, only about 10 percent of energy is transferred from one level to the next—this is the 10
- The energy flow, biomass, and numbers of members within an ecosystem can be represented in an ecological pyramid.
- **Toxins** in an ecosystem are concentrated and more dangerous for animals further up the pyramid.

0.43.1 Simpson's Diversity Index

Diversity Index = 1 (n/)^2

n = the total number of organisms of a particular species N = the total number of organisms of all species

0.44 Population Ecology

Population growth can be represented as the number of births minus the number of deaths divided by the size of the population.

r = (births – deaths)/N (r is the reproductive rate, and N is the population size.)

- **Carrying capacity**—the maximum number of individuals of a species that a habitat can support.
- The factors that limit a population are either density-independent or density-dependent.
- **Exponential growth** occurs when a population is in an ideal environment.
- Exponential growth occurs very quickly, resulting in a J-shaped curve.

0.45 Ecological Succession

- **Ecological succession** refers to the predictable procession of plant communities over a relatively short period of time (decades or centuries).
- The process of ecological succession in which no previous organisms have existed is called primary succession.
- Lichens are considered pioneer organisms.

0.46 Human Impact on the Environment

Human impact on the planet includes the following issues:

- greenhouse effect
- ozone depletion
- acid rain
- desertification
- deforestation
- pollution
- reduction in biodiversity
- introduction and spread of disease